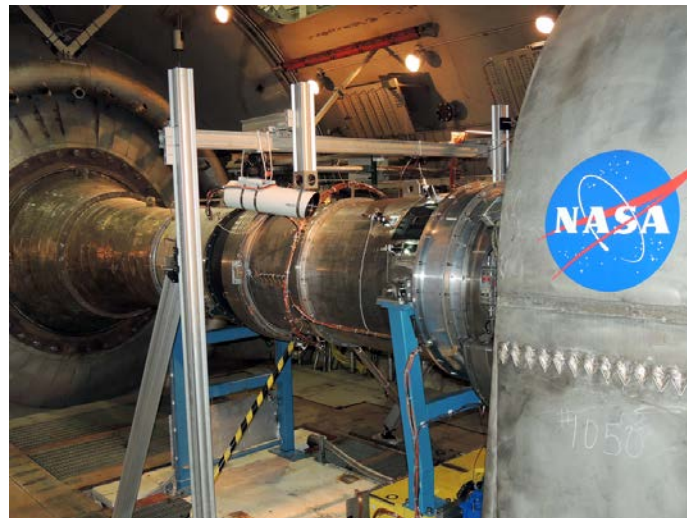
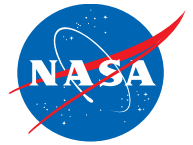


Ice Crystal Icing Engine Testing in the NASA Glenn Research Center's Propulsion Systems Laboratory (PSL) Altitude Investigation





PSL Selected Facility Capabilities

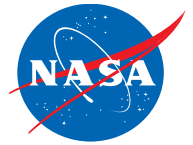
Characteristics and Performance

- Two engine test cells: PSL-3 and PSL-4 (24ft diameter by 39 ft. long)
- Simulate
 - Altitude: 5 to 90,000 ft
 - Conventional / Ice Crystal clouds (icing sys. combustion air limited to 330 lbm/s)
- Mach Number up to 4.0 (free jet Mach No. with auxiliary heater - to 6.0)
- Externally supplied compressed air (480lbm/s) and exhaust systems (750lbm/s)
- Thrust measurement: 50,000 lbf horizontal axis, 15,000 lbf vertical and lateral axes

Combustion Air System

- Main Supply
 - 480 lbm/sec @ ambient temperature and 55 psia
 - 380 lbm/sec @ ambient temperature and 165 psia
 - 240 lbm/sec @ 1100° F and 165 psia
 - 380 lbm/sec @ -40° F and 25 psia (PSL-3)
 - 30 lbm/sec @ -90° F and 25 psia (PSL-4)
- Cooling Air Supply
 - 100 lbm/sec @ ambient temperature and 55 to 165 psia

Facility Capabilities Edited from Information Listed at
<http://facilities.grc.nasa.gov/psl/index.html>

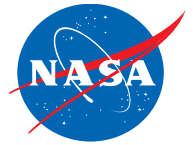


Inaugural Ice Crystal Icing Test conducted in February 2013

Test Article: Honeywell: ALF502-R5 (S/N LF01)

Accomplishments:

1. First ever ground test facility to demonstrate a full scale engine test duplicating a known high altitude ice crystal icing field event.
2. Developed facility capability, calibration and test methodologies for conducting full scale ice crystal icing turbofan engine tests.
3. Demonstrated capability to perform decent flight operation manipulating pressure and temperature during a 1000K ft/min.
4. Identified the existence of ice crystal icing boundaries/thresholds turning on and off ice crystal icing in this test article.
5. Demonstrated capability to perform “altitude scaling testing”—focus of current paper/presentation

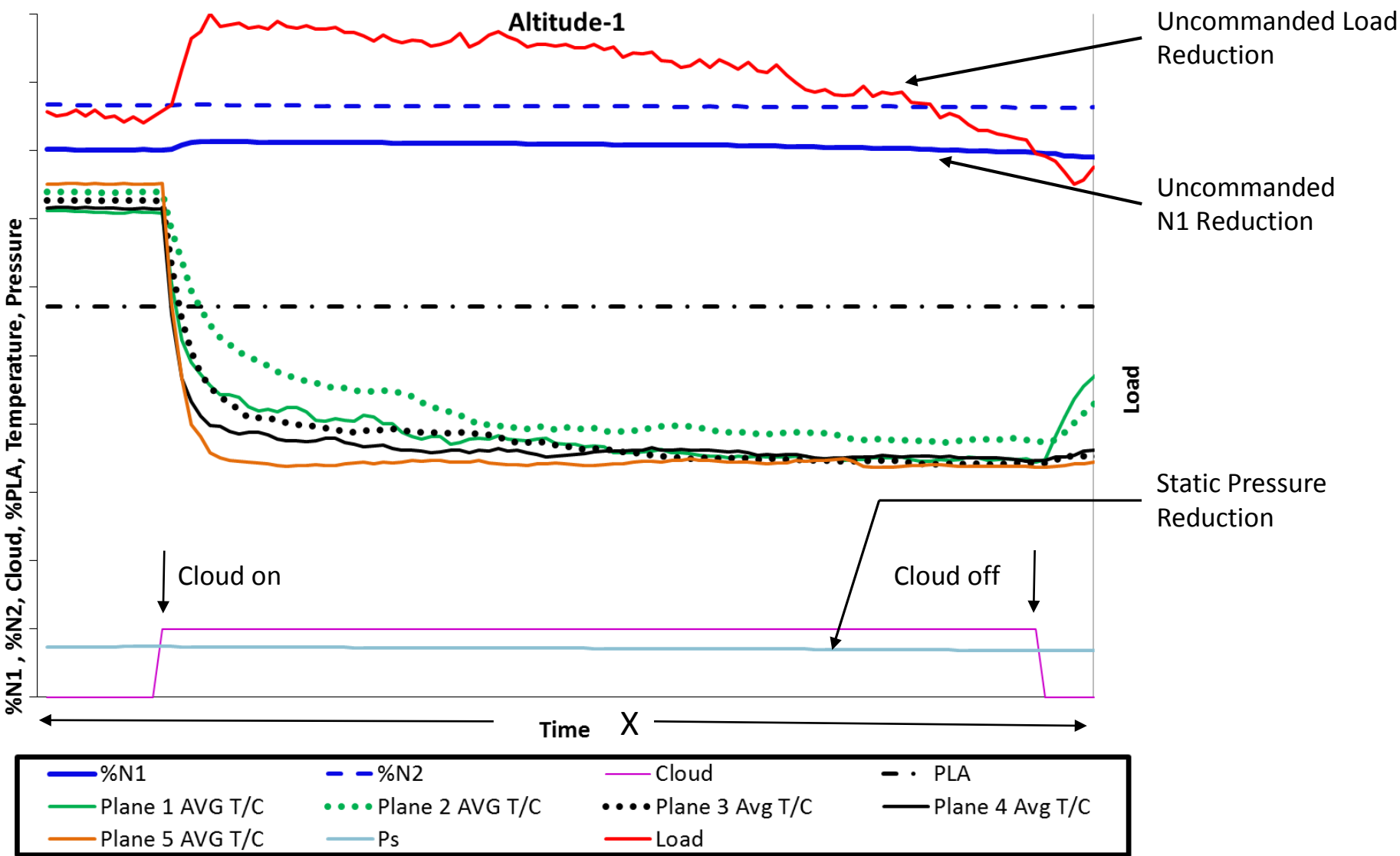


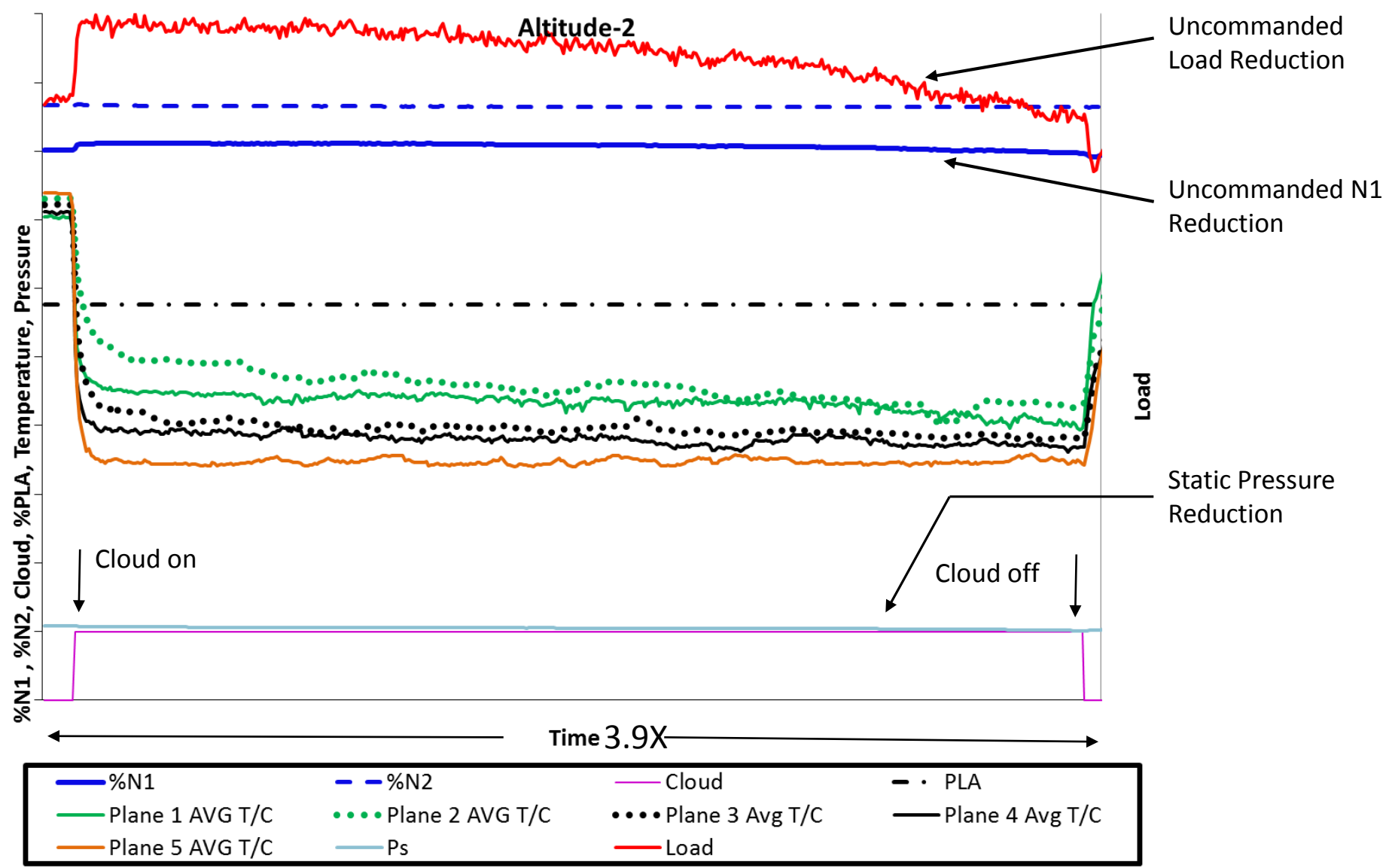
Ice Crystal Icing Loss of Power Event Successfully duplicated at various decreasing altitudes in PSL

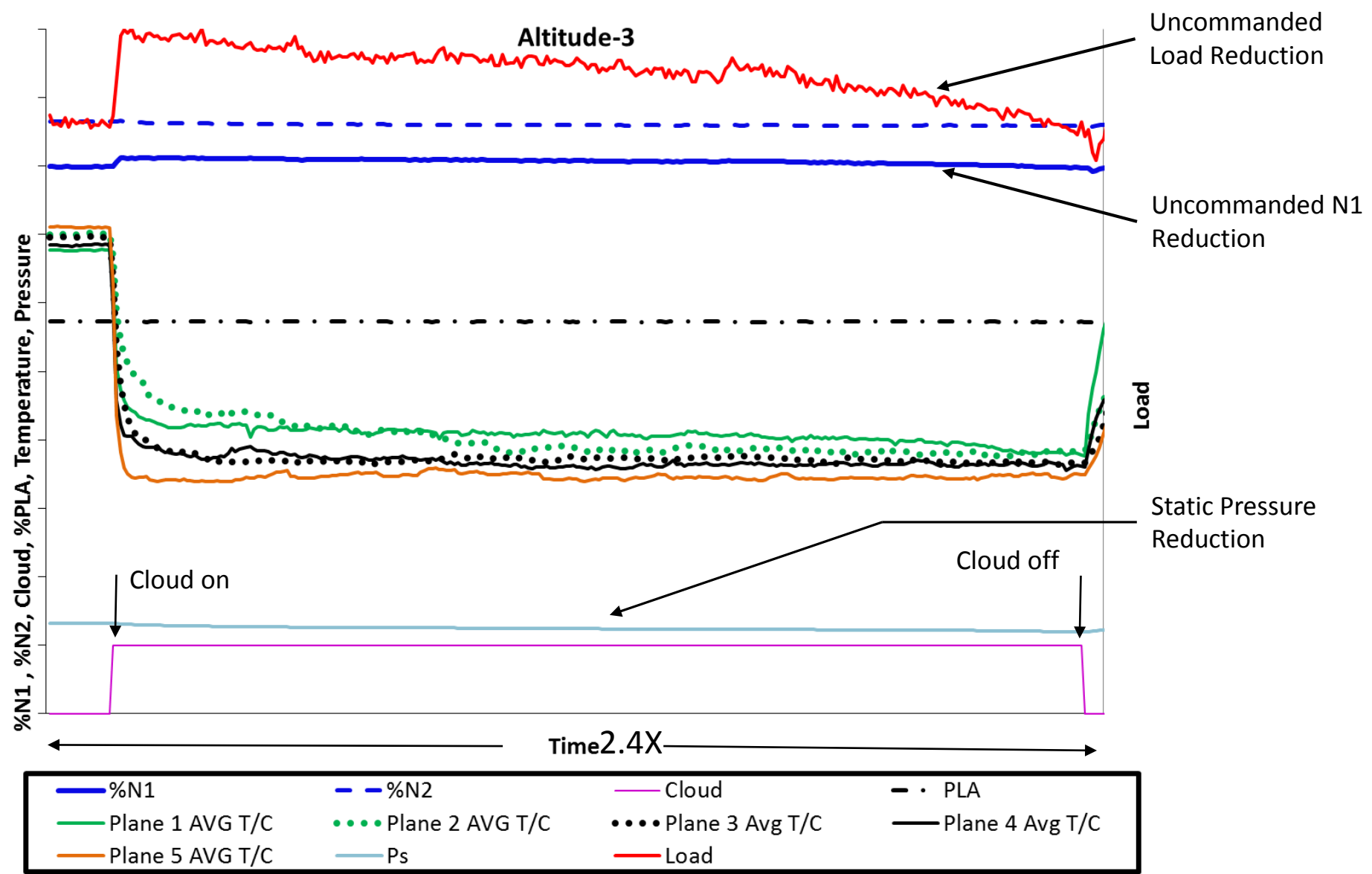
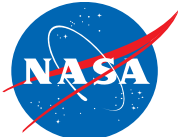
Testing Objective: To generate engine and facility data allowing NASA researchers to investigate the feasibility of ice crystal icing altitude scaling laws for turbofan engine icing research and development testing.

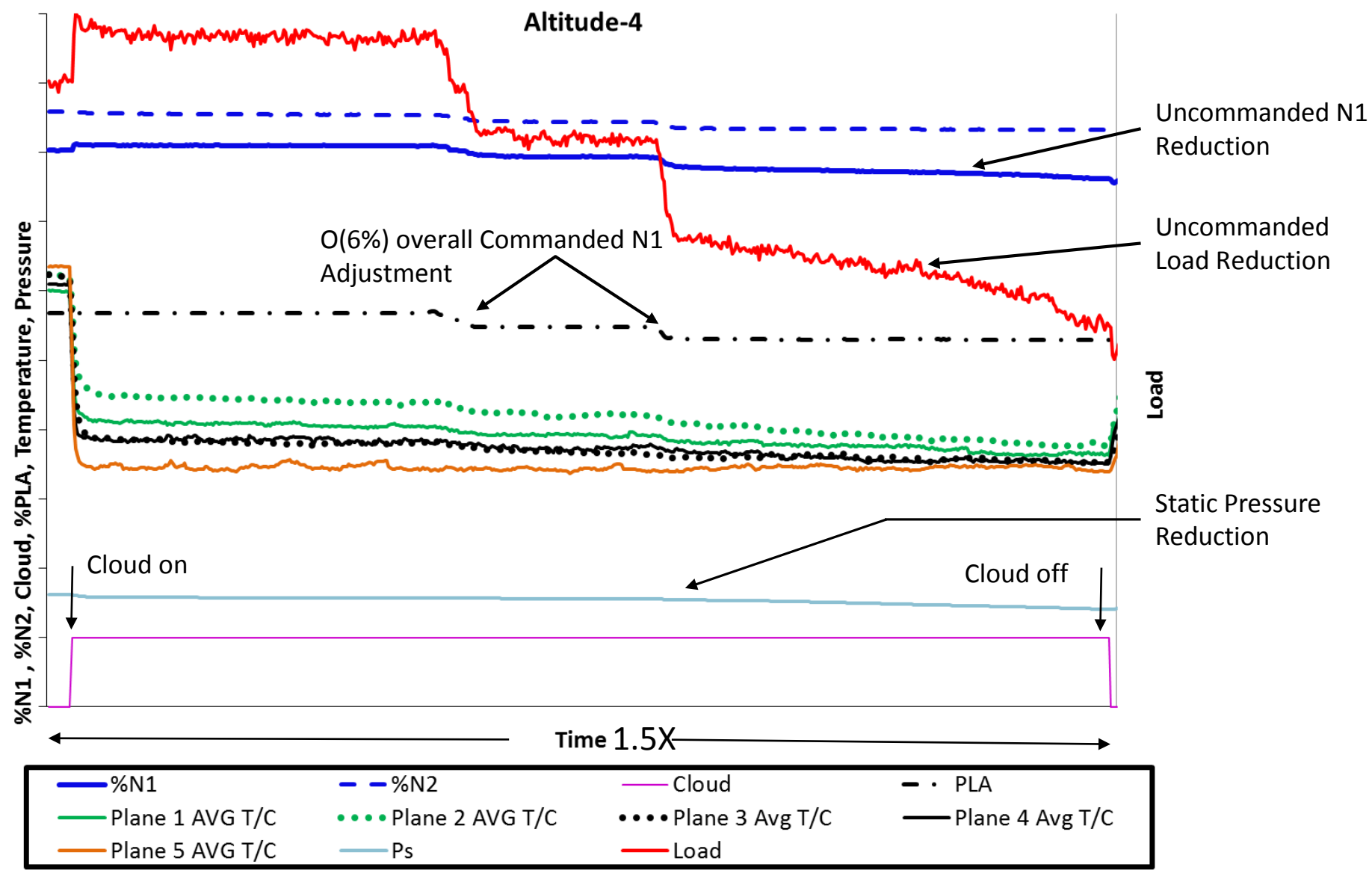
1. Altitude 1: The known high altitude ice crystal icing loss of power event
2. Altitude 2: lower than Altitude 1
3. Altitude 3: lower than Altitude 2
4. Altitude 4: lower than Altitude 3
5. Altitude 5: lower than Altitude 4

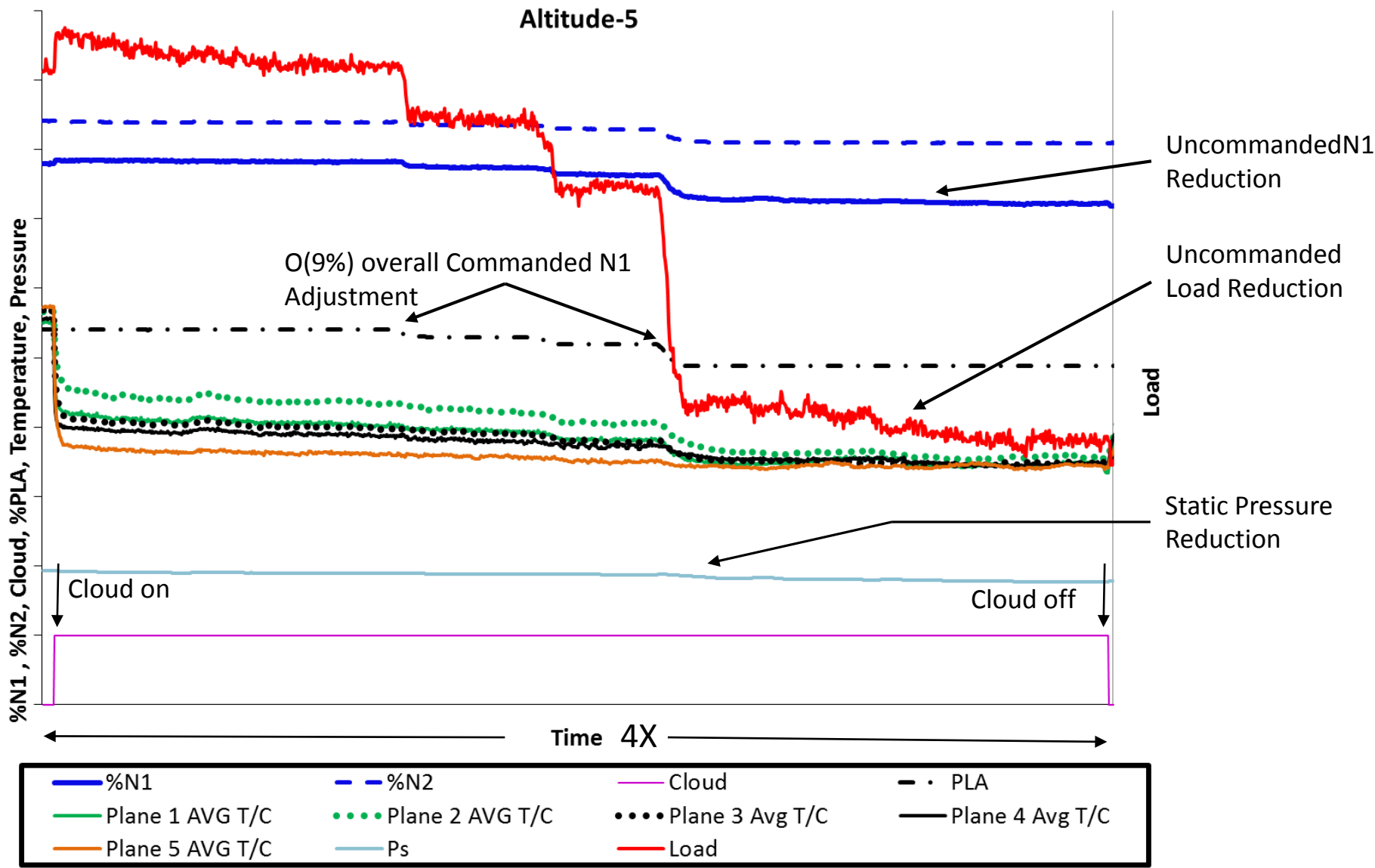
The ice crystal icing altitude investigation testing was conducted by systematically decreasing altitude and successfully duplicating the high altitude loss of power event at each altitude tested.

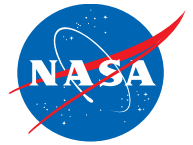












SUMMARY

- NASA PSL Successfully Demonstrated the Capability to Perform Altitude Scaling Engine Testing from an R&D perspective.

